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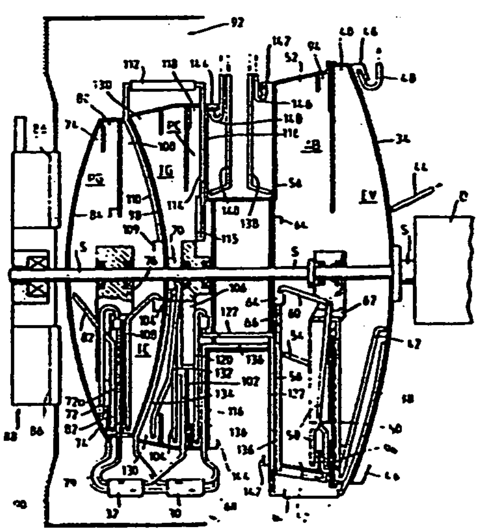
(54) A rotary absorption cycle heat machine

(57) A rotary absorption cycle heat machine comprises a vapour generator (PC), a condensor (IC/PC), an evaporator (EV) and an absorber (AB). Fluid is discharged onto an internal surface of the respective components at a radially inner location such that the fluid flows as a thin film radially outwardly. A thermally conductive structure is attached to the said internal surface (S) to deflect the liquid. The conductive structure may be metal fins, strands or filaments of metal mesh, gauze or porous metallic foam. The structure is bonded by either vacuum brazing or diffusion bonding to the internal surface.

Fig. 1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig. 1.

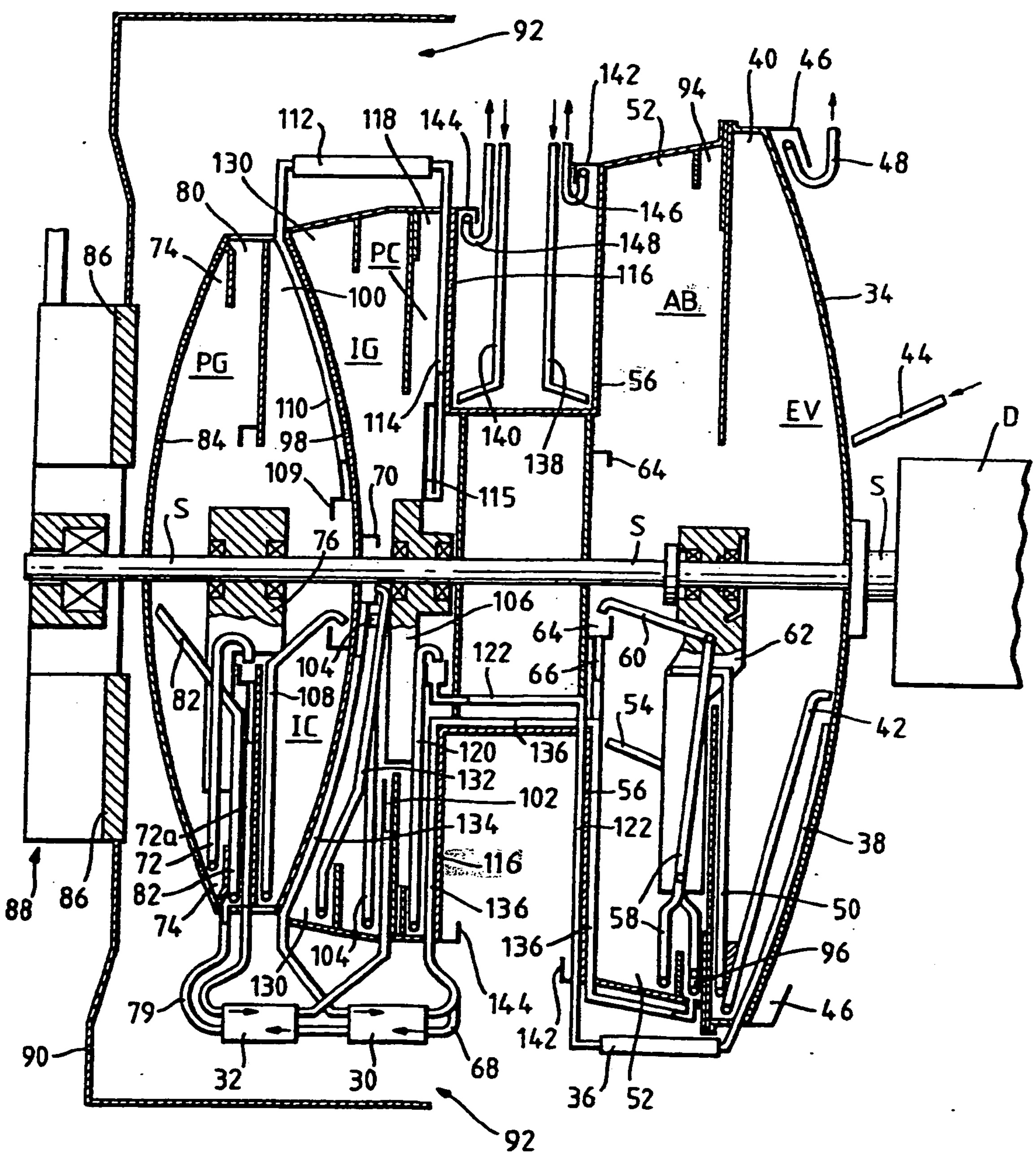

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Fig.2.

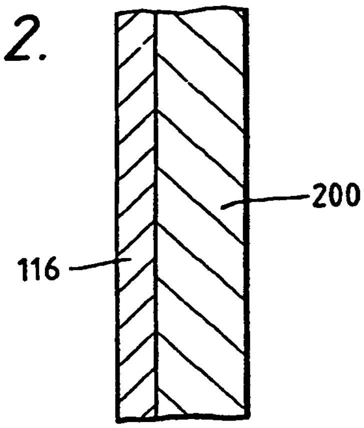

Fig.3.

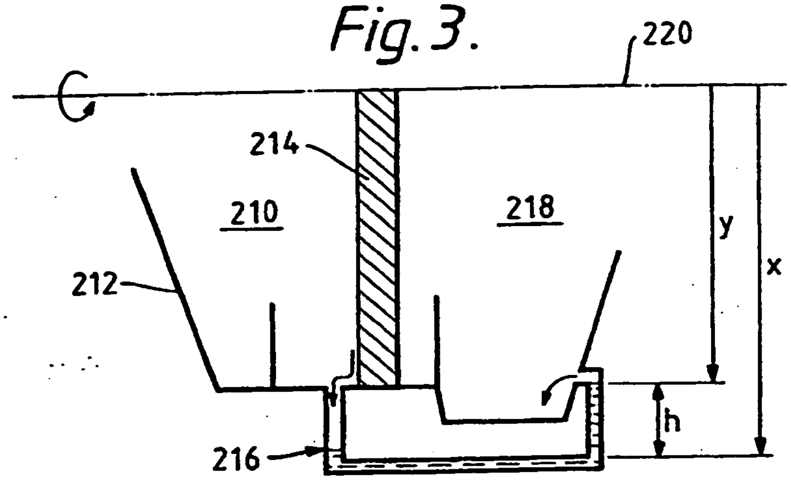

Fig.4.

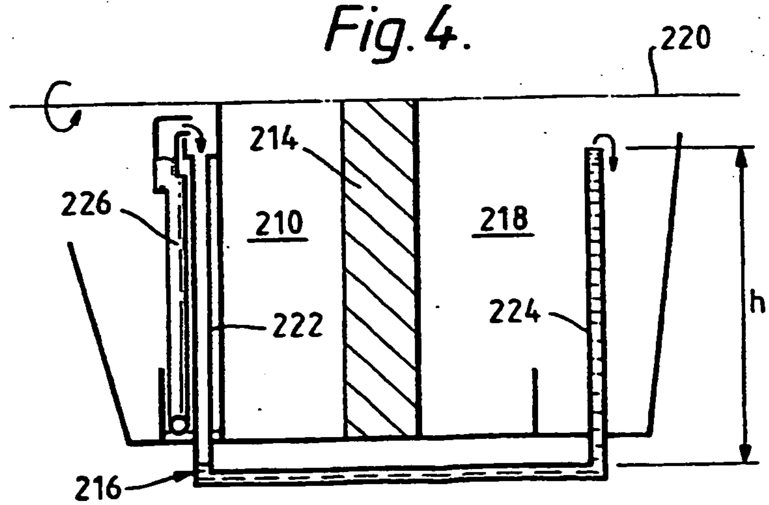

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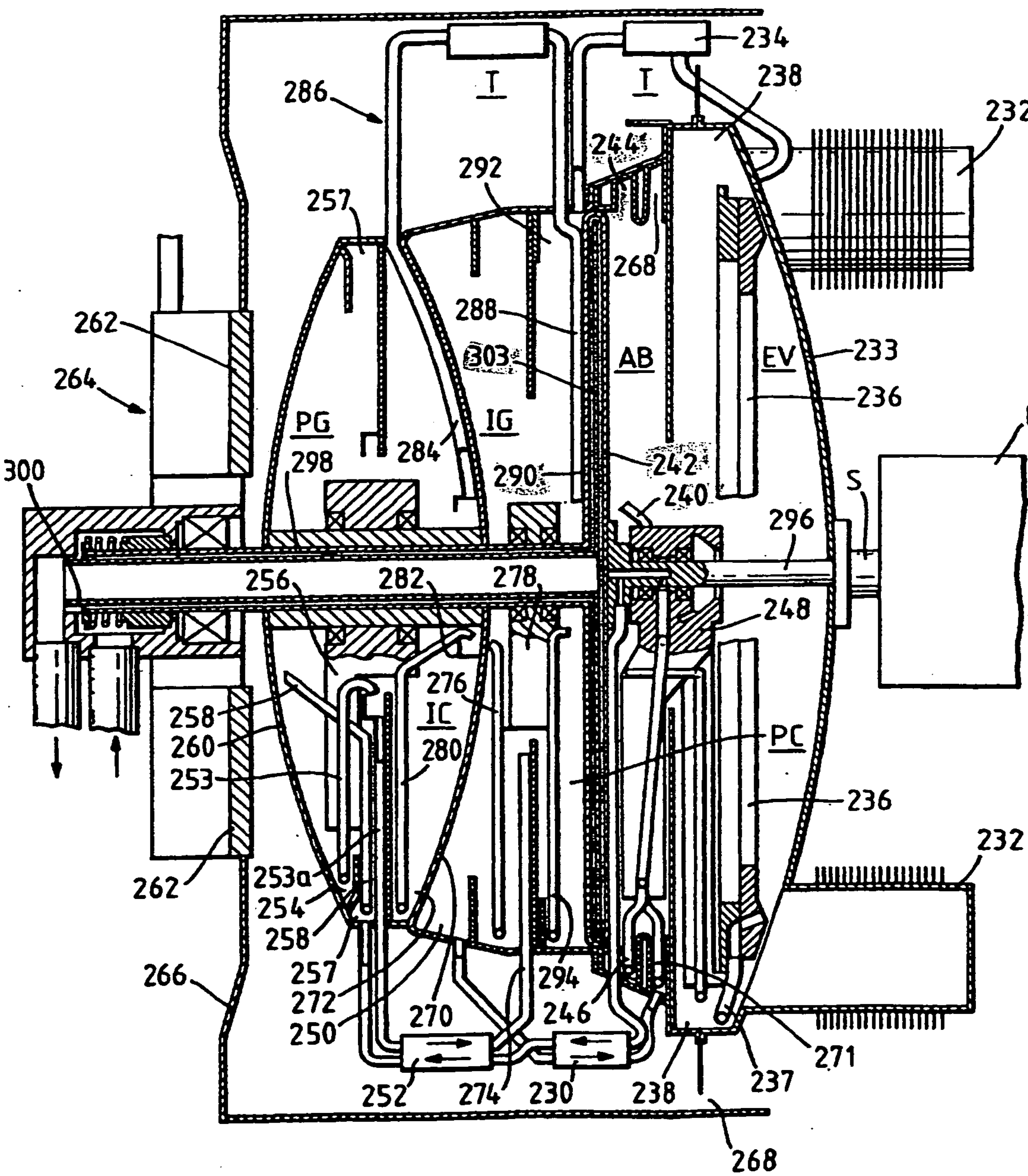
Fig. 5.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HEAT MACHINES

This invention relates to rotary heat exchange apparatus in which heat transfer between two media, of which one at least is in the liquid phase, is effected through the thickness of a plate which is rotatably driven.

One example of such apparatus is disclosed in prior European Patent Application No. 327230 which relates to rotary absorption cycle heat pumps comprising a rotary assembly including a vapour generator, a condenser, an evaporator and an absorber so interconnected as to provide cyclic fluid flow paths for a volatile fluid component and an absorbent liquid therefor. In EP-A-327230, heat exchange between heat donating fluids in the condenser and absorber and heat accepting liquid (eg. water) is effected across the thickness of respective walls associated with the condenser and absorber. The heat accepting liquid flows through a chamber which is bounded on opposite sides by the condenser and absorber walls, the chamber being flooded with the heat accepting liquid.

An object of the present invention is to provide improved efficiency of heat exchange across the thickness of a rotating plate forming part of rotary heat exchange apparatus.

According to the present invention there is provided an absorption cycle heat machine comprising a rotary assembly including a vapour generator, a condenser, an evaporator and an absorber so interconnected as to provide cyclic fluid flow paths for a volatile fluid component and an absorbent liquid therefor, means for feeding heat-accepting and/or heat-supplying fluid to the internal surface of a generally radially extending wall of at least one of the

generator, condenser, absorber and evaporator, said means discharging the fluid onto such internal surface(s) at a radially inner location such that, under the action `of centrifugal force, the fluid flows as a thin film liquid radially outwardly across said internal surface(s), and thermally conductive structure attached to said internal surface(s) so as to be in good thermal contact therewith, the thermally conductive structure comprising an array of elements distributed over said internal surface(s) in the radial and circumferential directions, said elements projecting away from said external surface(s) to provide surfaces over which flow of said thin film liquid is deflected as the liquid flows radially outwards over the internal surface(s), the extent of projection of said thermal structure in an axial direction being substantially greater than the thickness of said thin film.

In use, for a liquid having a given viscosity and density, the thickness of the liquid film may be controlled by selection of the speed of rotation of the plate and the rate of supply of the liquid to the plate.

The fluid supplied to said internal surface(s) may be in a gaseous phase such that, when discharged onto said one face, it condenses and then flows across the plate as a thin film liquid.

Preferably the thermal structure is such that it enhances the effective surface area of the surface to which it is attached by a factor of at least 3, more preferably at least 10, without projecting more than about 5 mm, more preferably no more than about 10 mm, from said internal surface(s) in a direction normal to such surface(s).

To avoid "blinding" of the thermal structure by the liquid and also to facilitate access of vapour to

the interior of the thermal structure, the latter conveniently has a voidage of at least 80%, more preferably at least 90%.

Preferably said thermal structure is provided on the internal surface of the absorber.

Advantageously, the thermal structure is so configured that it enhances mixing of fluids supplied to said internal surface(s). Thus, in the case of the absorber, where refrigerant in a vapour phase is to be absorbed by an absorbent in a liquid phase at the absorber wall, it is particularly advantageous if the thermal structure has a configuration which, in conjunction with the centrifugal forces developed during rotation of the assembly, enhances mixing of the refrigerant and absorbent.

The elements may be in the form of metal fins, or they may be constituted by the strands or filaments of a layer of metal mesh, such as Expamet (Registered Trade Mark), or of metal gauze bonded to said one face of the plate.

Preferably the elements are constituted by the strands or filaments of a porous metallic foam, such as that manufactured under the trade name Retimet, bonded to said one face of the plate. For further information relating to Retimet metallic foam, reference is made to the article entitled "Porous Metal Foams" by H. A. Bray published in Filtration & Separation May/June 1973.

Where the elements are provided by metal mesh, gauze or foam, the layer of material may be bonded to the plate by vacuum brazing or diffusion bonding so as to ensure good thermal contact between the strands or filaments and the plate.

Where the thermal structure is composed of strands or filaments, the strands or filaments are desirably bonded at nodes therebetween so as to afford

good thermal contact from one strand or filament to the next.

In practice, said elements of the thermal structure will have a high fin efficiency which can be achieved by selection of suitably thermally conductive material with an effective fin length which is not large in relation to the fin thickness.

The layer of material is preferably bonded to said internal surface(s) on one side only of the layer, the opposite side of the layer being free.

The invention has particular application to double effect machines in which the generator/condenser and/or the absorber/evaporator are constituted by two stages; for example, the generator/condenser may comprise a first stage comprising a primary generator and an intermediate condenser and a second stage comprising an intermediate generator and a primary condenser. Similarly, the absorber/evaporator may comprise a primary evaporator and an intermediate absorber, and an intermediate evaporator and a primary absorber. Such double effect machines are disclosed in greater detail in prior European Patent No. 149353, the disclosure of which is incorporated herein by reference. Thus, the absorption cycle heat machine defined above may comprise a double effect machine in which the internal surface of at least one of the primary and/or intermediate components (ie. generator, condenser, absorber and evaporator) is provided with thermal structure as aforesaid.

According to a more specific aspect of the present invention, the absorption cycle heat machine defined above comprises a double effect machine in which the generator/condenser comprises a first stage comprising a primary generator and an intermediate condenser and a second stage comprising an intermediate

generator and a primary condenser, in which the internal surface of the absorber is provided with thermal structure as aforesaid and in which the thermal structure is preferably in the form of porous metallic foam.

Where the evaporator/absorber comprises two stages, ie a primary evaporator and an intermediate absorber, and an intermediate evaporator and a primary absorber, preferably at least the primary absorber is provided with thermal structure as aforesaid.

Examples of rotary heat machines of the kind with which the present invention is concerned are disclosed in prior European Patents Nos. 119776 and 149353 and European Patent Application No. 327230.

In such rotary heat machines, a large pressure differential exists, and must be maintained, between the vapour generating means (which is a high pressure zone) and the evaporator means (which is a low pressure zone) during transfer of condensed fluid from condensing means associated with the high pressure zone to the evaporator means.

As disclosed in European Patent Application No. 327230, this may be achieved by means of throttle in the form of a U-tube which rotates with the machine and extends between the peripheral extremities of the vapour generating means and the evaporator means, the maximum pressure differential sustainable being determined by the height of the fluid column within the U-tube.

The machine specifically illustrated in European Patent Application No. 327230 is a single effect machine in that the vapour generation within the generating means and condensation of the vapour occurs once during each cycle of flow of working fluid through the machine. Typically, the pressure prevailing in the

vapour generating/condensing zone in such a single effect machine is of the order of 0.3 bar absolute and that prevailing in the evaporator is of the order of a few millibars absolute.

European Patent No. 149353 discloses a double effect machine in which vapour generation and condensation in the high pressure zone occurs in two vapour generator/condenser stages. In a double effect machine, the pressure prevailing on the high pressure side of the machine tends to be greater than is the case for a single effect machine. For example, in the first vapour generator/condenser stage, the pressure is typically of the order of 3.0 bar absolute and in the second vapour generator/condenser stage, it is typically of the order of 0.3 bar absolute. In other words, the pressure differential to be sustained may be considerably greater for a double effect machine.

Where a U-tube throttle arrangement as disclosed in European Patent Application No. 327230 is used to isolate the high and low pressure zones from each other, an increased pressure differential could be accommodated in the case of a double effect machine (or, if desired, a single effect machine) by extending the U-tube radially outwards. However, this has the drawback of increasing the overall radial dimensions of the machine. Similarly, if for instance in the case of a single effect machine, it is desired to reduce the radial dimensions of the machine in order to achieve a more compact design, there is a limit on the extent to which the lengths of the U-tube legs can be reduced while providing an adequate throttle to sustain the pressure differential.

According to another aspect of the present invention there is provided a rotary heat machine comprising at least two zones which, in operation of the

machine, contain working fluid at different pressures, and U-tube throttle means for transferring working fluid from the higher pressure zone to the lower pressure zone, characterised in that the U-tube throttle opens into each zone at a position radially inwards of the outer periphery of the respective zone and means is provided in the higher pressure zone for collecting working fluid from a radially outer region of that zone and feeding the working fluid radially inwardly to the U-tube throttle.

By these means the effective length of each leg of the U-tube may exceed the radial dimensions of the zones interconnected thereby without projecting unduly beyond the periphery of said zones.

Preferably, the legs of the U-tube throttle extend radially outwardly beyond the peripheries of the zones interconnected thereby so that the portion of the U-tube interconnecting the legs is located externally of said zones; however, because the invention makes it possible for the legs of the U-tube to be lengthened internally of the zones, it is conceivable that the U-tube throttle may, in suitable circumstances, be wholly accommodated within the peripheries of said zones.

The rotary heat machine may be a single effect machine in which case the higher pressure zone is constituted by a vapour generator/condenser stage and the lower pressure zone is constituted by an evaporator/vapour absorber stage.

Where the heat machine is a double effect machine having two vapour generator/condenser stages and an evaporator stage, each at a different pressure, U-tube throttle means and associated collecting and feeding means may be provided for the pressure differential between the two vapour generator/condenser

stages and/ or for the pressure differential between the lower pressure vapour generator/condenser stage and the evaporator stage.

The collecting and feeding means preferably comprises a rotationally restrained member located within the higher pressure zone and providing passageway means having a radially outwardly located inlet which, in operation of the machine, is immersed in rotating working fluid within a peripheral channel of the higher pressure zone, and a radially inwardly located outlet which discharges working fluid collected from the channel into the U-tube at a position radially inwards of the outer periphery of the higher pressure zone.

Preferably, the heat machine comprises heat transfer walls separating at least some of the different stages of the machine from each other and/or external heat and/or cooling sources, said heat transfer walls extending predominantly radially of the rotary axis of the heat machine such that heat exchange between the different stages and/or such stages and the external sources occurs through the thickness of said walls.

In a preferred embodiment of the invention, the machine comprises a rotatably mounted assembly comprising:

a first high pressure zone having generally radially extending walls respectively forming a primary vapour generator and an intermediate condenser;

a second intermediate pressure zone having generally radially extending walls forming an intermediate vapour generator and a primary condenser; and

a third low pressure zone having walls forming an evaporator and an absorber, at least the absorber wall(s) extending generally radially;

first throttle means provided between the first and second zones; and

second throttle means provided between the second and third zones;

characterised in that at least one of the throttle means comprises a U-tube which opens into each zone at a position radially inwards of the outer periphery of the respective zone and means is provided in the higher pressure zone of the two zones interconnected by the U-tube for collecting working fluid from a peripheral region of that zone and feeding the working fluid radially inwardly to the U-tube for transfer to the lower pressure zone.

Preferably said one throttle means is constituted by the first throttle means.

The second throttle means may likewise comprise a U-tube but, in this case, because the pressure differential will tend to be somewhat smaller than that existing between the first and second zones, it may open into the second and third zones at locations proximate the outer peripheries of those zones so that means for collecting and feeding working fluid radially inwardly is not required.

In the machines disclosed in European Patent Application No. 327230, heat transfer between the condenser and absorber of the machine and an external supply of heat exchange fluid, eg. water to be heated, is effected by means of a chamber which is rotatable with the assembly and is located between the condenser and the absorber, the fluid being supplied to the chamber through an annular passage in part of the rotary drive shaft of the assembly. A drawback with this arrangement is that the heat exchange fluid has to be supplied via a special seal and because the fluid supply circuit is operated fully flooded, heat exchange

efficiency may not be as high as desired and expedients have to be employed to improve heat exchange efficiency, eg. the provision of mesh on the surfaces contacted by the heat exchange fluid in order to increase the effective areas of such surfaces.

In order to provide an alternative form of heat exchange arrangement for effecting heat exchange between the fluids circulating internally within the rotary heat machine and external heat-accepting and/or heat-supplying fluids, according to a further aspect of the present invention there is provided an absorption-cycle heat machine comprising a rotary assembly including a vapour generator, a condenser, an evaporator and an absorber so interconnected as to provide cyclic fluid flow paths for a volatile fluid component and an absorbent liquid therefor, characterised in that means is provided for feeding heat-accepting and/or heat-supplying fluid to the external surface of a generally radially extending wall of at least one of the generator, condenser, absorber and evaporator, said means discharging the fluid onto such external surface(s) at a radially inner location such that, under the action of centrifugal force, the fluid flows as a thin film liquid radially outwardly across said external surface(s).

Although the heat accepting or heat supplying fluid will usually be in the form of a liquid when discharged onto the external surface of said wall, we do not exclude the possibility that the fluid may be of a gaseous nature such that, when discharged onto the wall, it condenses and then flows as a thin film liquid. For example, where the machine is used as a heat transformer, medium grade heat supplied to the generator may be in the form of steam which, on contact with the external surface of the generator wall,

condenses and then flows across that surface as a thin film of liquid.

The external surface(s) across which the thin film liquid flows may be advantageously be treated so as to assist the retention of a continuous film of liquid thereon. Such treatment, which may be chemical, eg. etching, or physical, eg. sand blasting, will in general be aimed at giving the surface an overall fine roughness.

The machine may be a double effect machine in which the generator/condenser and/or the absorber/evaporator are constituted by two stages; for example, the generator/condenser may comprise a first stage comprising a primary generator and an intermediate condenser and a second stage comprising an intermediate generator and a primary condenser. Similarly, the absorber/evaporator may comprise a primary evaporator and an intermediate absorber and an intermediate evaporator and a primary absorber. Such double effect machines are disclosed in greater detail in prior European Patent No. 149353, the disclosure of which is incorporated herein by reference.

Where said means is arranged to feed heat exchange liquid to two or more of said external surfaces, the liquid may be derived from different sources. Typically, the liquid supplied to the evaporator will be derived from a different source to that from which the liquid supplied to the absorber and/or condenser is derived. The absorber and the condenser may be provided with liquid from a common source or each may be provided with liquid from separate sources.

Where the condenser and absorber are supplied with heat exchange liquid from a common source, the liquid may be supplied either in parallel or in series

to the external surfaces of the condenser and absorber. For example, in the case where a series supply is adopted, the heat exchange liquid may be supplied to one of the external surfaces of the condenser or evaporator, collected at the outer radial location of that surface and then transferred to the other external surface, at a radially inner location, before being collected at a radially outer location of the latter external surface.

In one embodiment of the invention, the condenser and the absorber are bounded by generally radially extending walls which are in spaced confronting relation with each other, and said means includes liquid supply conduits extending between the confronting walls and having discharge openings located adjacent said walls to discharge heat exchange liquid onto each wall at a radially inner location, the condenser and the absorber each being provided with annular collecting channels adjacent radially outer locations of said external surfaces to collect the liquid after thin film flow thereof across the respective surfaces.

The invention will now be described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is an axial sectional view of a rotary absorption cycle heat machine in accordance with the invention;

Figure 2 is an enlarged schematic view showing thermally conductive layer material bonded to certain surfaces of the machine;

Figure 3 is a diagrammatic view illustrating the form of U-tube throttle already known in the art;
Figure 4 is a diagrammatic view of a U-tube throttle arrangement in accordance with the present invention; and
Figure 5 is an axial sectional view of a machine incorporating a U-tube throttle arrangement of the form shown in Figure 4.

Referring to the Figure 1, this shows a double effect machine which may be operated to effect heat pumping, cooling or heat transformation depending on the nature of the external heating/cooling sources with which the machine interacts. For the moment, the machine will be described with reference to its use in the heat pump mode. An aqueous working solution is circulated around a hermetically sealed circuit comprising an evaporator EV, an absorber AB, a pair of solution heat exchangers 30 and 32, a generator/condenser assembly (comprising a primary vapour generator PC, an intermediate condenser IC, an intermediate generator IG and a primary condenser PC) and back to the evaporator EV. The working solution comprises a mixture of a vaporisable component such as water (as the refrigerant) and an absorbent for the water, eg. a mixture of alkali hydroxides as disclosed in European Patent No. 208427.

The evaporator EV is bounded by a convexly dished wall 34 on to the internal surface of which condensed refrigerant is discharged, the condensed refrigerant being routed from the primary condenser PC via U-tube throttle 36 (which rotates with the machine) and being discharged from the open end of the leg 38 of the throttle 36 which terminates at a location proximate the axis of drive shaft S about which the machine rotates.

The drive shaft S is rotatably driven by reversible variable speed drive D.

The refrigerant discharged onto the internal surface of the evaporator wall 34 spreads under the action of centrifugal force as a thin film and flows towards an annular channel 40 at the outer periphery of the evaporator EV where unevaporated refrigerant collects and is recirculated via stationary pipe 42, arranged in the manner of a Pitot tube, back for discharge onto the evaporator wall 34 at a radially inner location. Excess refrigerant building up in the channel 40 is skimmed off by stationary pipe 50, acting as a Pitot tube, and is fed into absorber region of the machine where it combines with refrigerant rich solution in annular channel 52.

As it flows across the internal surface of the wall 34 after discharge from leg 38 or pipe 42, some of the refrigerant is evaporated by heat exchange with a flow of liquid acting as a source of low grade heat and flowing across the external surface of the wall 34. This liquid, which may be water, is discharged from a stationary conduit 44 onto the wall 34 at a radially inner location so that the water spreads as a thin film under the action of centrifugal force and flows across the wall 34 towards a radially outwardly positioned channel 46 from which it is scooped by stationary pipe 48 which is arranged in the manner of a Pitot tube.

The refrigerant vapour produced as a result of heat exchange across the thickness of the wall 34 travels axially towards the absorber AB where it is recombined with absorbent when it comes into contact with absorbent sprayed, via stationary pipe 54, onto the inner surface of a wall 56. The resulting heat of solution is transferred through the wall 56 to a load as described hereinafter.

The resulting refrigerant rich working solution collects in annular channel 52 and, by virtue of its kinetic energy, is transferred via stationary pipes 58 and 60 (forming, along with pipes 42 and 50, part of a rotationally restrained Pitot pumping arrangement 62 more fully described in European Patent Application No. 327230) into an annular channel 64 from where it is fed, via pipes 66 and 68 which rotate with the machine, to solution heat exchanger 30 in which it undergoes heat exchange with refrigerant depleted working solution from annular channel 70 associated with the intermediate generator IG. The refrigerant rich solution then passes through a second solution heat exchanger 32 in which heat exchange occurs with refrigerant depleted working solution transferred, via pipes 72 and 72a, from annular channel 74 associated with the primary generator PG, such transfer being effected by means of a rotationally restrained Pitot pump 76 operating in similar fashion to pump 62. The pipe 72 is restrained against rotation whilst the pipe 72a rotates with the rotary structure of the machine.

After passing through the heat exchanger 32, the refrigerant rich solution is fed via pipe 79 into annular channel 80 where it is scooped by pipe 82 forming part of the Pitot pump 76 and discharged onto the wall 84. The opposite side of the wall 84 is heated by radiant plaques 86 of burner 88 which is supplied with gas to produce high grade heat in the form of radiant energy from the plaques 86 and heat contained in the combustion products. Hot flue gases from the burner 88 flow over the external surface of the primary generator wall 84 shrouded by housing 90 and are exhausted via an annular slot 92 after passing over the heat exchangers 30 and 32 where further heat is given up

by the flue gases by heat exchange with the fluids flowing through exchangers 30 and 32.

The refrigerant rich solution impinging on the primary generator wall 84 is heated as it flows radially outwards by heat exchange across the thickness of the wall resulting in the vaporisation of the water component. The depleted component, consisting of absorbent and unvaporised water, flows across the face of the wall 84 and collects in annular channel 74 for eventual transfer back to the absorber via heat exchangers 32 and 30, the intermediate generator IG and annular channel 94 where it is scooped by pipe 96 forming part of the Pitot pump 62 and fed to pipe 54 for discharge onto the absorber wall 56. As a result of the vaporisation of the refrigerant, the pressure developed within the zone encompassing the primary generator PG and the intermediate condenser IC is typically of the order of 3.0 bar absolute.

The vaporised component comes into contact with the wall 98 common to the intermediate condenser IC and the intermediate generator IG where, as a result of heat exchange with cooled refrigerant depleted solution on the IG side of the wall 98, the refrigerant vapour on the IC side condenses and flows radially outwardly to annular channel 100. The fluid supplied to the IG side of the wall 98 is derived from channel 74 via pipes 72, 72a, 102 and 104, the latter forming part of rotationally restrained Pitot pump 106 arranged to operate in similar fashion to pumps 62 and 76. Because the refrigerant depleted solution from channel 74 is passed through heat exchanger 32 in heat exchange relation with relatively cool refrigerant rich solution derived from the absorber, it is relatively cool and therefore takes up heat from the water vapour on the IC side of the wall 98 to produce the desired condensation.

The refrigerant depleted solution supplied to the intermediate generator IG will, by virtue of heat transfer across the wall 98, generate further water vapour which will travel across to the primary condenser PC and condense.

The condensed refrigerant collecting in channel 100 is scooped by pipe 108 forming part of the Pitot pump 76 and transferred to an annular channel 109 proximate the rotary axis of the machine. From channel 109, the condensed refrigerant is fed radially outwardly by pipe 110 which constitutes one leg of U-tube throttle 112 which rotates with the machine. The other leg 114 of the throttle 112 feeds the condensate into the lower pressure zone (typically of the order of 0.3 bar absolute) encompassing the IG and the PC. The leg 114 folds back on itself (as shown at 115) so that the condensate is fed to a point proximate the rotary axis and then radially outwardly along section 115 so as to discharge onto the wall 116 across which the condensate flows radially outwardly, along with condensate derived from the refrigerant vapour produced at the intermediate generator IG, in heat exchange relation with a load as described hereinafter. The condensed refrigerant collects in annular channel 118 and is fed to the evaporator EV via stationary pipe 120, rotating piping 122, the U-tube throttle 36 and pipe 38. The pipe 120, which dips into channel 118, forms part of the Pitot pump 106.

Part of the condensate supplied to the channel 118 may be continuously recirculated and discharged onto the wall 116 at a point proximate the rotary axis by means of an unshown pipe which may form part of the Pitot pump 106. It will be seen that the throttles 36 and 112 are capable of providing, within the confines of the housing 90 (which, in any event has to have a

certain diameter in order to accommodate the outboard located heat exchangers 30 and 32), a column height exceeding the radial dimensions of the PG/IC and IG/PC zones. In this way, the throttles 36 and 112 enable a substantial pressure differential to be sustained between the different pressure zones of the assembly.

The refrigerant depleted solution discharged by pipe 104 onto the IG side of the wall 98 undergoes further vaporisation as it flows radially outwardly over the surface of wall 98 (as described above) and the solution remaining after vaporisation collects in channel 130 where it it is scooped by stationary pipe 132 and fed into annular channel 70 from which it is fed, by piping 134 rotating with the assembly, the heat exchanger 30 and piping 136 rotating with the assembly, to the channel 94 for discharge onto the AB side of the wall 56 and hence enrichment with refrigerant as described above.

The assembly described above is mounted as a unit for rotation about the axis of a shaft structure S driven by motor D The shaft structure S serves to rotatably mount the Pitot pumps 62, 76 and 106 which are restrained from rotating with the shaft either gravitationally or magnetically as disclosed in European Patent No. 327230.

At the external surfaces of the AB and PC walls 56 and 116, heat exchange takes place between the fluids in the AB and PC regions and a fluid forming a heat-accepting load, the heat transferred to the load being derived from condensation of refrigerant in the case of the primary condenser PC and from the heat of solution and from the condensed refrigerant in the case of the absorber AB. The load comprises fluid, eg. water circulating around a central heating system, and is fed by stationary pipes 138, 140 onto the external surfaces

of walls 56 and 116 at a radially inwardly located point so as to flow radially outwardly as thin films under the action of centrifugal force for collection in annular channels 142, 144 where the fluid is scooped by stationary pipes 146, 148 forming part of a circuit through which the fluid constituting the load flows.

If desired, the fluids supplied by pipes 138 and 140 may flow in a common circuit or they may flow in separate circuits. For example, where the heat-accepting fluid comprises water flowing around a central heating circuit, the collecting pipe 146 may be connected in series with the supply pipe 140.

It will be noted that the heat-accepting fluid is provided in a non-flooded manner in contrast with the arrangements disclosed in European Patent No. 327230, with the advantage that thin films of the heat-accepting fluid can be utilised on the heat transfer surfaces with consequent improvement in heat transfer characteristics. Also, this technique is less sensitive than a flooded technique (as in European Patent No. 327230) to problems arising when the fluid is contaminated or dirty.

In accordance with the present invention, at least the internal surface of the wall 116 has a thermally conductive structure attached thereto. Referring to Figure 2, the thermal structure is in the form of a layer 200 of porous metal foam bonded on one side only to the external surface of wall 116, the opposite side of the layer 200 being free and unsupported. The porous metal foam comprises Retimet metal foam which is a material having good thermal conductivity and a high surface area per unit volume. The layer 200 is bonded to the wall 116 by vacuum brazing or diffusion bonding so as to ensure good thermal contact between the layer and the wall which will likewise have good thermal conductivity. The

thickness of the layer 200, ie. its depth in a direction parallel to the axis of rotation of the machine, is significantly greater (preferably by at least an order of magnitude) than the thickness of the thin film of liquid so that the thin film, as it flows over the strands or filaments forming the layer 200, is caused to follow a labyrinthine path extending in three dimensions through the layer, ie. radially, circumferentially and axially.

Typically, the layer of Retimet material is of the order of 0.5 cm thick and its specific area is of the order of 25 cm^{-1} thereby providing an area enhancement factor of the order of 12.5 compared with the area of a single plane surface.

In addition to the wall 116 being provided with layer 200, it will be understood that other walls of the assembly may be provided in the same manner with a layer of material for the same purpose, eg. the internal surfaces of the walls 34, 56 and 84.

In the illustrated embodiment, the working solution is shown as being fed from the absorber AB to the primary generator PG and then returning via the intermediate generator IG. Various modifications are however possible within the scope of the invention; for example, the working solution may be fed from the absorber to the intermediate generator first and return via the primary generator or it may be split and fed as two fractions, one to the primary generator and the other to the intermediate generator. In such modifications, the configuration of the pumping arrangements would differ from those shown in the illustrated embodiment but are not described here since the form of the pumping arrangements required in such alternative embodiments will be readily apparent to those skilled in the art.

The illustrated embodiment has been described with reference to use of the machine in a heat pump mode. It may also be used as a heat transformer; for instance, both the evaporator and the primary generator may be supplied with medium grade heat and the primary condenser may provide a low grade heat output while the absorber may provide an output of useful grade heat.

Referring to Figure 3, this shows diagrammatically a throttle arrangement similar to that employed in the single effect machines illustrated in European Patent Application No. 327230, the disclosure of which is incorporated herein by reference. Zone 210 represents a high pressure zone in which the refrigerant is vaporised at the wall 212 from the working solution (comprising the refrigerant and an absorbent), condensed at wall 214 and transferred, via U-tube throttle 216, to low pressure zone 218 in which the evaporation and absorption mechanisms of the cycle take place. The rotary axis of the assembly is depicted by reference numeral 220. It will be seen that the maximum pressure differential that can be sustained for a given rotational speed of the machine is governed by the height h of the column of working solution. In general, the pressure differential that can be sustained is given by the formula:

$$\Delta p = \frac{1}{2} d w^2 (x^2 - y^2)$$

where d is the density of the liquid forming the column;
w is the rotational velocity of the assembly;
x and y are respectively the outer and inner radii of the column.

As shown in Figure 4, the pressure differential sustainable is considerably increased

without unduly increasing the extent to which the U-tube projects radially outwardly beyond the outer peripheries of the zones 210 and 218. This is achieved by extending the legs 222, 224 of the U-tube 216 so that they terminate proximate the axis 220 and providing a pumping arrangement 226 for collecting working solution at the outer periphery of the zone 210 and feeding it radially inwardly for transfer into the U-tube 216 and hence to the zone 218. The pumping arrangement 226 operates on the Pitot principle and comprises a tube which is restrained against rotation and collects fluid rotating at the periphery of the zone 210 so as to make use of the kinetic energy of the fluid to feed the same radially inwardly without the need for a separate source of drive for the pump.

Referring to Figure 5, this shows a double effect machine which may be operated to effect heat pumping, cooling or heat transformation depending on the nature of the external heating/cooling sources with which the machine interacts. For present purposes, the description herein will be confined to the machine when used in the heat pump mode. An aqueous working solution is circulated around a hermetically sealed circuit comprising an evaporator EV, an absorber AB, a first solution heat exchanger 230, a second solution heat exchanger 252, a primary vapour generator PG, an intermediate condenser IC, an intermediate generator IG, a primary condenser PC and back to the evaporator EV. The working solution comprises a mixture of a vaporisable component such as water (as the refrigerant) and an absorbent for the water, eg. a mixture of alkali hydroxides as disclosed in European Patent No. 208427. The evaporator EV is constructed generally in accordance with the teaching in European Patent Application No. 327230 and comprises a plurality of angularly spaced

tubes 232 of elliptical cross-section mounted on wall 233 and into which condensed refrigerant routed from the primary condenser PC via U-tube throttle 234 is injected by means of a distributor device 236 (described more fully in European Patent Application 327230) which, by means of pipe 237, collects the water from an annular channel 238 at the periphery of the zone encompassing the evaporator EV and the absorber AB. In the evaporator tubes 232, some of the water is evaporated by heat exchange with a flow of ambient air (or other source of low grade heat) and the resulting vapour is recombined with absorbent when it comes into contact with absorbent sprayed, via pipe 240, onto a wall 242. The resulting heat of solution is transferred through the wall 242 to a load as described hereinafter.

The resulting water rich working solution collects in annular channel 244 and, by virtue of its kinetic energy, is transferred via pipe 246 (forming part of a rotationally restrained Pitot pumping arrangement 248 more fully described in European Patent Application No. 327230) to solution heat exchanger 230 in which it undergoes heat exchange with water depleted working solution from annular channel 250 associated with the intermediate generator IG. The water rich solution then passes to a second solution heat exchanger 252 in which heat exchange occurs with water depleted working solution transferred, via pipes 253 and 253a, from annular channel 254 associated with the primary generator PG, such transfer being effected by means of a rotationally restrained Pitot pump 256 operating in similar fashion to pump 248. The pipe 253 is restrained against rotation whilst the pipe 253a rotates with the rotary structure of the machine.

After passing through the heat exchanger 252, the water rich solution enters annular channel 257 where it

is scooped by pipe 258 forming part of the Pitot pump 256 and discharged onto the wall 260. The opposite side of the wall 260 is heated by radiant plaques 262 of burner 264 which is supplied with gas to produce high grade heat in the form of radiant energy from the plaques 262 and heat contained in the combustion products. Hot flue gases from the burner 264 flow over the external surface of the primary generator wall 260 shrouded by housing 266 and are exhausted via an annular slot 268 after passing over the heat exchangers 230 and 252 where further heat is given up by the flue gases by heat exchange with the fluids flowing through exchangers 230 and 252.

The water rich solution impinging on the primary generator wall 260 is heated as it flows radially outwards by heat exchange across the thickness of the wall resulting in the vaporisation of the water component. The depleted component, consisting of absorbent and unvaporised water, flows across the face of the wall 260 and collects in annular channel 254 for transfer back to the absorber via heat exchangers 252 and 230, the intermediate generator IG and annular channel 268 where it is scooped by pipe 271 forming part of the Pitot pump 248 and fed to pipe 240 for discharge onto the absorber wall 242. As a result of the vaporisation of the water, the pressure developed within the zone encompassing the primary generator PG and the intermediate condenser IC is typically of the order of 3.0 bar absolute.

The vaporised component eventually comes into contact with the wall 270 common to the intermediate condenser IC and the intermediate generator IG where, as a result of heat exchange with cooled water depleted solution on the IG side of the wall 270, the water vapour on the IC side condenses and flows radially

outwardly to annular channel 272. The fluid supplied to the IG side of the wall 270 is derived from channel 254 via pipes 253, 253a, 274 and 276, the latter forming part of rotationally restrained Pitot pump 278 arranged to operate in similar fashion to pumps 248 and 256. Because the water depleted solution from channel 254 is passed through heat exchanger 252 in heat exchange relation with relatively cool water rich solution derived from the absorber, it is relatively cool and therefore takes up heat from the water vapour on the IC side of the wall 270 to produce the desired condensation. The water depleted solution supplied to the intermediate generator IG will, by virtue of heat transfer across the wall 270, generate further water vapour which will travel across to the primary condenser PC and condense.

The condensed water collecting in channel 272 is scooped by pipe 280 forming part of the Pitot pump 256 and transferred to an annular channel 282 proximate the rotary axis of the machine, the pipe 280 in this embodiment being the counterpart of the pipe 226 in Figure 4. From channel 282, the condensed water is fed radially outwardly by pipe 284 which constitutes one leg of U-tube throttle 286 which rotates with the machine. The other leg 288 of the throttle 86 feeds the condensate into the lower pressure zone (typically of the order of 0.3 bar absolute) encompassing the IG and the PC. The condensate is supplied to a point proximate the rotary axis and discharges onto the wall 290 so as to flow radially outwardly, along with condensate derived from the water vapour produced at the intermediate generator IG, into annular channel 292 and thence to the evaporator EV via the U-tube throttle 234, channel 238 and distributor 236.

Part of the condensate supplied to the channel 292 is continuously recirculated by means of pipe 294 forming part of the Pitot pump 278. It will be seen that the throttle 286 is capable of providing, within the confines of the housing 266 (which, in any event has to have a certain diameter in order to accommodate the outboard located heat exchangers 230 and 252), a column height exceeding the radial dimensions of the PG/IC and IG/PC zones.

It will be noted that the assembly of pipes 253a, 274 and heat exchanger 252 are also arranged to function as a U-tube throttle in the manner described with reference to Figure 4. In this case, the working fluid used comprises refrigerant-depleted solution fed to the pipe 253a by pipe 253 and, because the refrigerant depleted solution will have a higher specific gravity (assuming that the absorbent is a mixture of hydroxides as previously described), the column height needed to sustain the pressure differential is somewhat less than in the case of the throttle 286 which means that the lengths of pipes 253a and 274 can be made correspondingly shorter as shown.

The assembly described above is mounted as a unit for rotation about the axis of a shaft structure S driven by motor D. The shaft structure includes a solid section 296 and a hollow section comprising a pair of concentric inlet and outlet tubes 298, 300 for the feeding a fluid medium to be heated through a chamber 302 bounded by the walls 242 and 290 associated with the absorber AB and primary condenser PC respectively, the chamber 302 being centrally partitioned so that the heat accepting fluid flows initially over the primary condenser wall 290 and then over the absorber wall 242 before exiting via the outlet tube 300. The shaft structure in addition serves to mount the Pitot pumping

arrangements 248, 256 and 278 via respective bearing assemblies so that the pumps can remain stationary while the remaining machine components rotate with the shaft structure.

In the illustrated embodiment, the invention is described with reference to a double effect generator/condenser. It will be appreciated however that the invention is also applicable to machines using a single effect generator/condenser and single effect absorber/evaporator (as described in European Patent Application No. 327230) or in multi-effect machines as described in European Patent No. 149353.

CLAIMS

1. An absorption cycle heat machine comprising a rotary assembly including a vapour generator, a condenser, an evaporator and an absorber so interconnected as to provide cyclic fluid flow paths for a volatile fluid component and an absorbent liquid therefor, means for feeding heat-accepting and/or heat-supplying fluid to the internal surface of a generally radially extending wall of at least one of the generator, condenser, absorber and evaporator, said means discharging the fluid onto such internal surface(s) at a radially inner location such that, under the action of centrifugal force, the fluid flows as a thin film liquid radially outwardly across said internal surface(s), and thermally conductive structure attached to said internal surface(s) so as to be in good thermal contact therewith, the thermally conductive structure comprising an array of elements distributed over said internal surface(s) in the radial and circumferential directions, said elements projecting away from said external surface(s) to provide surfaces over which flow of said thin film liquid is deflected as the liquid flows radially outwards over the internal surface(s), the extent of projection of said thermal structure in an axial direction being substantially greater than the thickness of said thin film.

2. A machine as claimed in Claim 1 in which the thermal structure is such that it enhances the effective surface area of the surface to which it is attached by a factor of at least 3.

3. A machine as claimed in Claim 1 in which the thermal structure is such that it enhances the effective surface area of the surface to which it is attached by a factor of at least 10.

4. A machine as claimed in Claim 1, 2 or 3 in which said thermal structure projects no more than 10 mm, from said internal surface(s) in a direction normal to such surface(s).

5. A machine as claimed in Claim 1, 2 or 3 in which said thermal structure projects no more than 5 mm, from said internal surface(s) in a direction normal to such surface(s).

6. A machine as claimed in any one of claims 1 to 5 in which the thermal structure has a porosity of at least 80%.

7. A machine as claimed in any one of claims 1 to 6 in which the thermal structure is provided on the internal surface of the absorber.

8. A machine as claimed in any one of claims 1 to 7 in which said elements are constituted by the strands or filaments of a porous metallic foam, metal mesh or metal gauze.

9. A machine as claimed in Claim 8 in which said foam mesh or gauze is bonded to the plate by vacuum brazing or diffusion bonding so as to ensure good thermal contact between the strands or filaments and the plate.

10. A machine as claimed in Claim 8 or 9 in which said foam, mesh or gauze is bonded to said internal surface(s) on one side only of the layer, the opposite side of the layer being free.

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